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Title

A systematic review and meta analysis of the longevity of anterior and posterior all-ceramic crowns

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Crowns, all-ceramic, systematic review, critical review, longevity, meta analysis, anterior and posterior restorations, clinical

Abstract

Background

Clinical experience suggests that there is a difference in survival between anterior and posterior all ceramic restorations.

Objectives

This systematic review compared the difference in survival for full coverage all-ceramic materials used in adults to restore anterior or posterior vital teeth, not involved with fixed dental prostheses, but opposed by teeth.

Data and sources

Searches using Medline, Embase, and the Cochrane Library, including hand searches, with the inclusion criteria containing all-ceramic full coverage crowns in human adults over 17 years of age, prospective and retrospective studies, opposed by teeth, periodontal pocketing ≤5mm, but not involving implant supported crowns or non-vital teeth. All papers were published between 1980 and March 2014 and available in English. From the selected studies a meta analysis was undertaken. The chi square test, I^2, Begg's and Egger's test were analysed and the publication bias was assessed using a Funnel plot. The,Kappa scores were 0.63, 0.88, and 0.81 at each selection stage.

Study selections

Pooled data produced 1112 anterior crowns with 73 failures (6.5%) and 1821 posterior crowns with 166 failures (9.1%) with a follow up time from 36 to 223 months. Relative risk meta-analysis of the 14 selected papers demonstrated that anterior all-ceramic crowns were 50% less likely to fail than posterior all-ceramic crowns (p=0.001).

Conclusion

These results indicate that there were differences in failure between anterior and posterior all ceramic crowns but the difference was only 3%. Although this has clinical relevance and some caution is needed when prescribing all ceramic posterior crowns the difference was relatively small.

Clinical significance

The clinically relevant results of this review, based on currently available data, demonstrate a need for some caution when considering posterior all-ceramic crowns. Lithium disilicate restorations were observed to have higher failures on anterior restorations and more research is needed to investigate why.

Introduction

Ceramic materials are used to restore teeth, including the provision of conventional tooth supported single crowns. All-ceramic crowns are considered favourable in the anterior dentition compared to metal-ceramic and metal crowns due to their aesthetic qualities [1-3]. However, there is a debate over the appropriate use of these materials in the posterior dentition.

A direct comparison of the longevity of anterior and posterior all-ceramic crowns has not been made prior to this study[4 – 11].. Four of these systematic reviews [4-7, 11] reported some data on the differences between anterior and posterior crowns, but focused on fracture rates [4-6, 11] and survival [6, 11] of all types of crowns. Wasserman *et al* [11], reported the outcome of In-Ceram crowns, in a pseudo systematic review and within this paper three studies contained data comparing anterior to posterior crowns. From these, Scherrer *et al* [12] reported, in a retrospective clinical trial, that a 'clear' difference was observed in the fracture of anterior (2% of 45 crowns) and posterior (13% of 23 crowns) for In-Ceram Alumina crowns over a five-year period. McLaren and White [13], reported 3 year survival rates of 98% for anterior crowns and 94% for posterior crowns, and Segal (2001) [14] in another clinical study, reported higher survival rates of posterior crowns (99.2%) compared to anterior crowns (98.9%).

Three other systematic reviews report partial data on the outcome for anterior and posterior all-ceramic crowns [4-6]. Wang *et al* [5], reported the core or veneer annual fracture rates for all ceramic crowns over 3 years and observed statistically significant

differences (p=0.001) between anterior (0.6%) and posterior (1.1%) core fractures but not for veneer fractures. Heintze and Rousson [4] reviewed fracture rates of leucite-based all-ceramic crowns (Empress™) and observed statistical differences in the higher fracture rates for molar (6.7%) and canine (2.9%) crowns compared to premolars (2.9%) and incisor (2.3%) crowns. Pjetursson *et al* [6] reported the 5-year survival of all-ceramic crowns compared to metal ceramic crowns. These authors subdivided all-ceramic crowns into four material groups, with all showing higher annual fracture rates on posterior teeth and statistical differences observed in glass-ceramics (p=0.008) and InCeram™ (p=0.028).

Despite these data there remains questions on the longevity and outcome of all-ceramic materials used to restore posterior teeth [3] irrespective of material and cause of failure. The aim of this review was to compare the difference in longevity for any all-ceramic material used to restore anterior and posterior teeth, not involved with fixed dental prostheses or posts.

Methods – eligibility and search strategy

Medline, EMBASE and the Cochrane library bibliographic databases were searched electronically. Two searches, were conducted on each database, and combined. The first search, used keywords linked to Medical Subject Headings (MeSH) and indicated as follows, (1) 'ceramics' (MeSH); (2) 'dental ceramic'; (3) searches (1) and (2) combined with 'or'; (4) 'tooth crown' (MeSH); (5) 'crowns' (MeSH); (6) 'tooth crown* or crown* or dental crown*'; (7) searches (4), (5) and (6) combined with 'or'; (8) searches (3) and (7) combined with 'and'. The second search used keywords, (1) 'dental porcelain' (MeSH); (2) 'dental porcelain* or dental laminate*'; (3) searches (1) and (2) combined with 'or';

(4) ‘tooth crown’ (MeSH); (5) ‘crowns’ (MeSH); (6) ‘tooth crown* or crown* or dental crown*’; (7) searches (4), (5) and (6) combined with ‘or’; (8) searches (3) and (7) combined with ‘and’. Following this, the searches were combined with the primary outcomes. Manual hand searches were subsequently conducted through the Prosthodontic literature using the International Journal of Prosthodontics, the International Journal of Computerized Dentistry, the Journal of Oral and Maxillofacial Implants, and the Journal of Prosthodontics. “Grey literature” was also searched on OpenSIGLE (opensigle.insit.fr) and the Web of Science. These searches were complemented by communications with various authors and manufacturers of ceramic materials. All the articles were pooled and duplicates removed.

The inclusion criteria were reports containing all-ceramic full coverage crowns in human adults over 17 years of age, using clinical, randomized controlled trials, prospective and retrospective studies in situations where the restored teeth were opposed by teeth, periodontal pocketing ≤5mm, but not involving implant supported crowns or non-vital teeth. All papers were published between 1980 and March 2014 and available in English. Exclusion criteria, included laboratory studies, opinion-based articles, ceramic crowns used with fixed dental prostheses, partial coverage crowns, single case reports and abstract reports.

Data collection

The titles were independently screened at different times by two of the authors. Where there was doubt or lack of agreement the titles were discussed and a decision made as to whether to include or exclude the articles. Cohen’s Kappa coefficient was calculated to measure inter-reviewer agreement at each stage. Where abstracts or full papers were

not available the article was excluded.

Analysis

Given the variation between the studies, and lack of volume of directly comparable data available, the studies were assessed at a binary level of success or failure. Failure included any event that affected the crown, examples being chipping, fracture, caries, loss of the crown, whereas, success recorded no adverse events. Where data were not clear, or if only anterior or posterior crowns were individually reported, these papers were excluded. Anterior crowns were defined from canine to canine and remaining teeth were classified as posterior restorations. The binary data allowed comparative analysis of crowns using relative risk meta-analysis. The inequality in the lengths of the studies complicated direct comparison between studies. Therefore, similar length studies were analaysed in sub-groups using mean follow-up periods of 3 and 4 years (group 1), 5 and 6 years (group 2) and 7 or more years (group 3).

Descriptive statistics were used to summarise the study characteristics and relative risk meta analysis carried out using the 'metan' command in stata (Data Analysis and Statistical software, version 12, Stata corp, USA). To account for study variations, random effects models were used in the meta-analysis, for both within and between study variations in effect sizes. Relative risk of failure of anterior crowns compared to posterior crowns and the 95% confidence interval were calculated separately for each study. The chi square test was used to assess for heterogeneity in the data beyond the value of chance and the percentage of heterogeneity in the data were calculated using the heterogeneity measure I^2. Bias due to small study effects were assessed using Begg's and Egger's test and publication bias assessed visually using a Funnel plot drawn using

'metafunnel' command in stata.

Results

A total of 3937 articles were obtained from the initial title searches (Figure 1 and Table 1). On applying the inclusion and exclusion criteria these were reduced to 320 abstracts with a Kappa score of 0.68 (95% Confidence Interval (95% CI) 0.63 – 0.73). The abstracts were reduced to 119 full articles, with a Kappa score of 0.88 (95% CI 0.83 – 0.94) and finally 14 papers [14-27] selected for data analysis, with a Kappa score 0.81 (95% CI 0.70 – 0.91) consisting of 9 prospective and 5 retrospective studies.

The selected studies were published between 1994 and 2013, with follow up periods of each study varying from 36 months [17] up to 223 months [26]. The largest number of crowns analysed within a single study were 343 anterior crowns and 789 posterior crowns, and both sets of data occurred within the same study [25]. With such a wide variation in follow up periods, the studies were arranged into three categories, group (1) comprised of studies with a follow up period of 3 to 5 years (4 studies), group (2) between 5 to 6 years (8 studies) and group (3) 7 or more years (2 studies).

The pooled data produced a total of 1122 anterior crowns and 1821 posterior crowns for analysis. Group (1) contained 143 anterior crowns, with 2 failures (1.4%) and 200 posterior crowns with 6 failures (3%). Group (2) had 742 anterior crowns, with 27 failures (3.6%) and 1492 posterior crowns, with 110 failures (7.4%). Group (3) had 237 anterior crowns, 44 failures (18.6%), and 109 posterior crowns, 50 failures (38.8%). Combining all the data from of all the groups, produced 73 anterior (6.5%), and 166 posterior failed crowns (9.1%).

The materials investigated were slip cast alumina, leucite reinforced, pure alumina, zirconia and lithia disilicate (Table 1). Furthermore, 6 studies reported on slip cast alumina crowns, with 413 anterior crowns and 714 posterior crowns placed. Of the slip cast alumina crowns 10.4% failed in the anterior region and 9.2% in the posterior region. The single paper, from Group (1), analysing 47 anterior and 28 posterior leucite based crowns, reported 0% and 3.6% respectively. The 4 studies analyzing pure alumina core ceramic crowns, Group (2), reported the outcome for 189 anterior crowns, with 3.2% and 247 posterior crowns with 10.9% failures. Zirconia crowns were analysed in one study in Group (2) and reported that 15 of 343 anterior crowns failed (4.4%), and 71 of 789 posterior crowns failed (9.0%). The final material to be analysed were lithia disilicate crowns and represented in two studies in Group (2) and (3), 9 of 130 anterior crowns failed, at 6.9%, and 1 of 43 posterior crowns failed, at 2.3%.

The results of meta-analysis for the three groups are summarised in Table 2. The relative risk for the failure of anterior all-ceramic crowns compared to posterior all-ceramic crowns along with the 95% confidence intervals are given in the Table 2. The lowest relative risk, of 0.20, 0.15 and 0.49, for the failure of anterior crowns was observed by Sorensen *et al* [18], Sorrentino *et al* [23] and Rinke *et al* [26] in groups 1, 2 and 3 respectively and the maximum relative risk of 2.16 was observed by Gehrt *et al* [27] in group 3. The contribution of each group in the meta-analyses group is shown in the 'weight' column in the Table 2. The pooled (overall) relative risk for the failure of anterior crowns compared to posterior crowns was 0.65, 0.5 and 0.73 for the three groups respectively. The results (group 2) indicated that the risk of anterior crown failure was around 50% less likely compared to posterior crown for the follow up period of 5 to 6 years and this was statistically significant (p=0.001). The value I^2,

variation in relative risk attributable to heterogeneity, for groups 1, 2 and 3 were 0%, 0% and 51.4% respectively and. similarly, the between-study variance (tau- squared) were 0, 0 and 0.58 for groups 1, 2 and 3 respectively. All these measures showed that the studies were homogeneous for all three groups.

The p values from the Begg's and Egger's test for studying the small study effects in group (2) meta-analysis were 0.81 and 0.49 respectively. This showed that there was no evidence for small study bias in the meta-analysis. To investigate as to whether there was any publication bias, further analysis was carried out using funnel plot. The funnel plot (Figure 2), shows that the publication bias and the relative risk is within the pseudo 95% confidence Interval and therefore the analysis does not show any publication bias.

Discussion

The aim of this study was to investigate the outcome of all-ceramic crowns on anterior and posterior teeth, using the available data, and these results indicate that posterior crowns carry a greater risk of failure and so support the hypothesis. This finding, has the potential to influence decision making for clinicians when considering these restorations for posterior teeth. Despite these results some caution is needed on the interpretation. From the selected studies, five each were based on slip cast alumina and alumina cores, two for lithia disilicate and one each for zirconia and leucite reinforced materials. Therefore to interpret these to all materials must carry some caution but the overall message suggests that all ceramic crowns on posterior teeth have more risk. Most of the studies reported the failure of posterior restorations exceeded the anterior apart from the studies those by Toksavul and Gehrt, both reporting on lithia disilicate but the reason for this was unclear. However, based on this study some caution is

needed when using them for anterior situations.

The materials analysed in the 14 papers selected for statistical analysis, broadly represented the current materials available at the time of publication, as set out in a recent article classifying all-ceramic materials [35]. Although glass ceramics, such as Dicor™, and leucite reinforced glass ceramics, such as Empress™, are no longer in use, one study analysed reported leucite reinforced glass ceramics [18]. This study showed no significant difference to the other studies selected for statistical analysis and, as the paper met the inclusion criteria, it could not be removed from the study. The number of ceramic materials, their development over the period of study, and the variety in the description of the results made it difficult to differentiate between them in the statistical analysis. It would have been preferable to have a larger number of materials to study and so allow comparisons made between the materials. There were a reasonable number of studies in Group (2) representing medium term trials (5-6 years), but there was a dearth of longer studies available, which is not uncommon. The ideal scenario would be longer-term clinical trials, preferably randomized controlled trials. The absence of these studies might reflect why new materials are introduced without long-term data to support them.

The search criteria were designed to be as broad as possible, allowing the collection of as many relevant articles as possible and resulted in the identification of 3937 papers, a significant total, and comparable to the results of other systematic reviews [4-7]. The risk with too many keywords was excluding studies as reported by other authors [28]. By narrowing the parameters of the search by the use of so many keywords, the number of articles that contained all the keywords was reduced. The structure of the multiple

searches conducted in this current review compensated for the number of keywords, allowing a large number of titles to be captured. The lower Kappa score (>0.6) calculated at the initial selection stage may have reflected the difficulty in sorting through such a large number of titles. The Kappa scores at the abstract and full paper level (>0.8) showed reasonably high agreement. The eligibility criteria included the exclusion of papers with data for post-restored teeth. This resulted in the loss of potential data from a number of articles and was in different in approach to other systematic reviews in this area [4-6]. However, the aim of this study focused on vital teeth and did not complicate the analysis for teeth with posts, where failure from other mechanisms may confuse the outcome.

There were no randomized controlled trials (RCTs) fulfilling our selection criteria. This reflects the findings of other recent systematic reviews analyzing all-ceramic crowns [4-7] and the general lack of RCTs in general in Dentistry [29]. As a result of the outcome from the search we had to include reports where anterior and posterior crowns were reported in the same study but often for a different hypothesis than the one we chose. Of the 14 papers selected for statistical analysis, 9 were prospective and 5 retrospective studies. Although Heintze and Rousson [4] reported that the quality of studies for their review was low, there was no quality assessment of the studies or data, which is consistent with the methods of other systematic reviews on all-ceramic crowns, including this present study. Kelly [30] reported a lack of well-defined criteria for clinical trials in Dentistry. Anusavice [31], and Chadwick *et al* [32] discussed the difficulty in obtaining homogenous data for comparison in systematic reviews. The experience of this review was no different and guided the decision to classify the outcome data to success or failure. Therefore, any reported adverse event concerning a

crown was considered a failure and this in turn allowed relative risk meta-analysis to be calculated. The meta-analysis allowed the information from different studies to be combined and an effectiveness of a health care intervention calculated and expressed as a relative risk [33]. In effect this allowed a value to be placed on outcomes, and permitted comparison.

The relative risk (RR) of the studies was calculated as the ratio of proportion of failures in anterior crowns to proportion of failures to posterior crowns. As the RR differed for each study, the meta analysis provided a consolidated value for the failure of anterior crowns compared to posterior crowns based on those studies included in the analysis. To address the variability of RR, 95% confidence intervals for the RR were calculated for the individual studies and for the overall combined RR. To facilitate the comparison of the RR and its 95% confidence interval the overall RR was depicted in the forest plot. To identify any publication bias within the studies, the funnel was plotted and the presence or absence of publication bias was confirmed if any of the points for each study fell within the boundary in the funnel plot. The funnel plot was drawn only for group-2 and could not be carried out for the other two groups as there were only few studies.

In this review, any reported problem with a crown was considered a failure. Problems, or events, reported in the studies selected for analysis were categorized as biological or technical. Ideally, the mode of failure would have given more information but each author used different failure criteria and so a much broader analysis was undertaken. As an example, technical failures were commonly classified as fractures either in the core or veneer, or a result of debonding. Some fractures were reported in the papers as

repaired by polishing, however these were still noted as a failure. Biological failures commonly included caries, loss of vitality, and tooth fracture. The hypothesis tested if all-ceramic crowns were more likely to fail in the posterior dentition, given the greater masticatory forces associated in this area. On closer inspection, and considering greater tooth reduction required for all-ceramic crowns and the likely equigingival crown margins, the biological and technical failures may be expected to be more prevalent in anterior teeth. Therefore, no prior assumptions, and so no omissions, were made, and the focus and scope of this study were not restricted to one mode of failure or another. These reasons also explain why the decision was made to exclude root filled teeth as their restoration involves significant tooth reduction and so it is impossible to identify if any failure was a direct cause of the material or the remaining tooth tissue.

The data in this study were analysed per tooth (or per crown) and was dictated by the way the data were presented in the studies. Ideally, the data would have been analysed per patient, but this was not possible. The total of 1122 anterior crowns and 1821 posterior crowns pooled in this paper is reasonable given the number of studies but cannot be considered representative of all the crowns used in general practice. Given that all-ceramic crowns are considered favourable in the anterior region due to their superior aesthetic qualities [3], it is surprising that more posterior crowns were reported. Most of the crowns were reported in Group (2), with a follow-up period 5 to 6 years, and this could be considered clinically relevant though for many patients it might be considered a limited amount of time. However, long-term data is fraught with difficulties and only a few authors have successfully accomplished it (Walton *et al*) [34]. It is not possible to compare these results to other systematic reviews, as the outcomes assessed were different, however as a percentage failure it is clear that posterior

crowns are more likely to fail than those in the anterior region. The assumption that failure will increase over time seems justified as the failure percentage increases for both anterior and posterior crowns from Group (1) through to Group (3).

Further randomized controlled trials, with greater numbers, and conducted over a longer period of time, would be of benefit in improving our understanding of this subject. In conclusion, and considering the limitations of this self funded study, was that anterior all-ceramic crowns were statistically significantly, 50% less, likely to fail than posterior all-ceramic crowns over a period between 36 and 223 months,. Based on the current data clinicians need to be more cautious about using all-ceramic crowns to restore posterior teeth.

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Table 1 – the 14 studies selected for meta-analysis

Study	Follow Up Period in Months	Group	Study Type	Material	No. Anterior Crowns	Anterior Failed (%)	No. Posterior Crowns	Posterior Failed (%)
Scotti 1995	44	1	Prospective	Slip Cast Alumina core (inceram)	25	0 (0)	38	1 (2.6)
Probster 1996	56	1	Prospective	Slip cast alumina core (inceram)	28	1 (3.6)	67	2 (3)
Haselton 2000	36	1	Retrospective	Slip cast alumina core (inceram)	43	1 (2.3)	67	2 (3)
Sorensen 1998	36	1	Retrospective	Leucite reinforced glass ceramic (Empress)	47	0 (0)	28	1 (3.6)
Oden 1998	60	2	Prospective	Pure alumina core (allceram)	17	0 (0)	83	9 (10.8)
Segal 2001	72	2	Prospective	Slip cast alumina core (inceram)	117	2 (1.7)	369	3 (8.1)
Walter 2006	72	2	Prospective	Pure alumina core	61	2 (3.3)	46	4 (6.3)

				(allceram)				
Toksavul 2007	60	2	Prospective	Lithia disilicate (Empress II)	56	1 (1.80	23	0 (0)
Kokubo 2009	66	2	Prospective	Pure alumina core (allceram)	37	3 (8.1)	64	9 (14)
Sorrentino 2009	72	2	Retrospective	Pure alumina core (allceram)	74	1 (1.4)	54	5 (9.3)
Kokubo 2011	60	2	Prospective	Cad/cam Slip cast alumina core (inceram)	37	3 (8.1)	64	9 (14.1)
Monaco 2013	60	2	Retrospective	Various Zirconia	343	15 (4.4)	789	71 (9)
Rinke 2011	223	3	Retrospective	Slip cast alumina core (inceram)	163	36(2.2)	109	49 (45)
Gehrt 2013	96	3	Prospective	Lithia disilcate (e.max)	74	8 (10.8)	20	1 (5)

Table 2 : the results of meta analysis with 95% confidence intervals

Study	RR	95% Confidence Interval		% Weight
		LCL	UCL	
Group-1 (3 and 4 years)				
Sorensen 1998	0.2	0.008	4.78	17.88
Haselton 2000	0.78	0.073	8.33	31.95
Scotti 1995	0.500	0.021	11.81	17.94
Probster 1996	1.2	0.11	12.67	32.22
Pooled RR	0.65	0.17	2.48	100.00
Group-2 (5 and 6 years)				
Oden 1998	0.27	0.015	4.03	2.19
Toksavul 2007	0.26	0.053	29.92	1.71
Monaco 2013	0.49	0.28	0.84	58.34
Kokubo 2011	0.58	0.17	1.99	11.92
Kokubo 2009	0.58	0.17	1.99	11.92
Segal 2001	1.39	0.23	8.24	5.41
Walter 2006	0.38	0.072	1.97	6.28
Sorrentino 2009	0.15	0.018	1.21	3.82
Pooled RR	0.5	0.33	0.76	100.00

Group-3 (7 years or more)

Gehrt 2013	2.16	0.29	16.29	27.16
Rinke 2011	0.49	0.34	0.7	72.84
Pooled RR	0.74	0.19	2.72	100.00

LCL = Lower Confidence Limit UCL=Upper Confidence Limit

RR = Relative Risk of failure of Anterior crowns compared to Posterior Crowns.

Figure 1- flow chart of the study selection

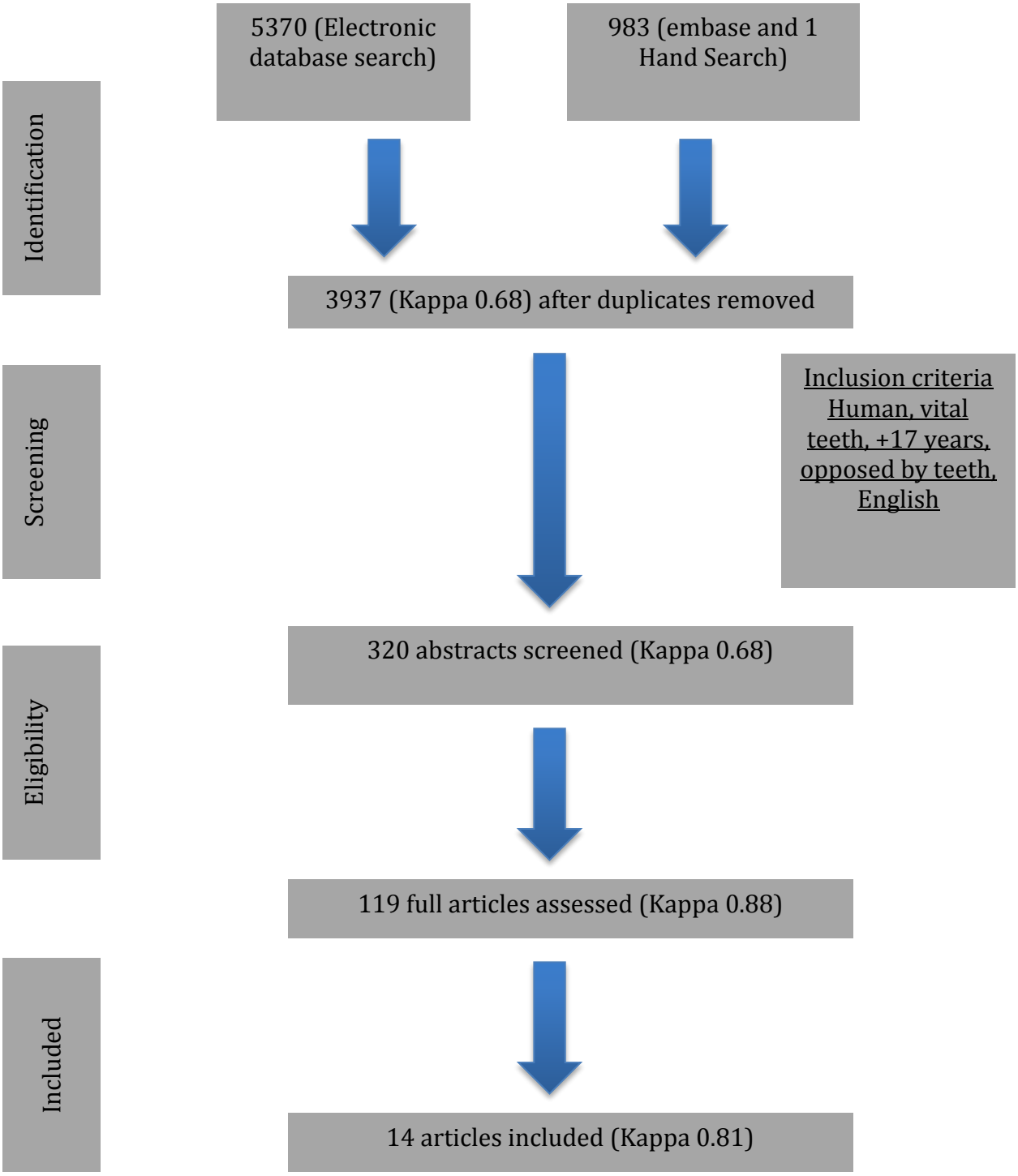
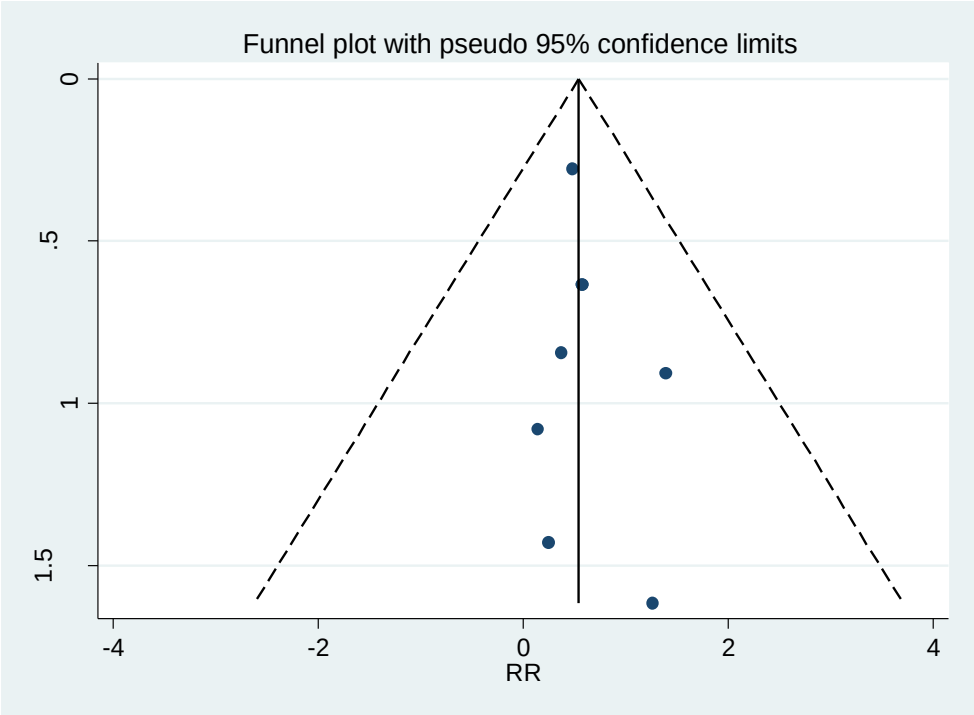


Fig 2 – The funnel plot with the 95% confidence limits for Group-2.



* As the same value is reported in Kokubo 2011 and Kokubo 2009, the two points coincides and hence there are only 7 points in the funnel plot instead of 8.